Physically-based modelling techniques for multisensory simulation

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Physically-based modelling techniques developed in parallel in computer graphics, computer music and virtual realities. Most of them are dedicated to a category of model depending on the synthesized phenomena: sound, movement, etc.

When one needs to build a multisensory scene (for example to be manipulated by using a force feedback transducer), most often, various exogenous models are used, one for each sensory modality. Models are then inter-related by some inter-control means, often asynchronous. As an example, in virtual realities, sound is most often simply obtained by triggering pre-recorded samples – and, eventually, processing them (e.g.: apply a spatialization algorithm) – when an event occurs in the visual scene.

The framework of enactive interfaces, however, emphasizes the unicity of human perception, and in parallel the need of a particularly high and thin correlation between the gesture of the user and the various multisensory stimuli generated. Indeed, implementing exogenous interconnected sound model, visual model, and sometimes haptic models, hardly enables the close interaction needed between the various stimuli feedback one need. Making these models behave in a truly coherent manner in order to let the user believe that he perceives/manipulates an object is still a major difficulty.

Conversely, though it is still rarely done and difficult, on can also try to design a single multisensory physically-based model. In such a case, as a vis-à-vis of the unicity of human sensori-motricity, the model is unique and generates all the sensory outputs in response to gesture in one shot. However, only a very few modelling framework qualify for such multisensory simulation. We review below the mass-interaction framework.

The Mass-interaction framework

Within the mass-interaction modular framework (also called particle modelling), a model is obtained by assembling, as a network, modules of two types: masses and physical linear and non-linear interactions. The technique differs from mass-spring meshes. It relates more to works like the pioneering [Greenspan, 73], or the more recent [Cadoz et al., 93] [Greenspan, 97] [Luciani et al., 91], since it consists in a specific algorithmic implementation of Newtonian mass-point physics. More precisely, differences include:

- It comes along with a number of linear and non-linear interactions (collisions, bow-like interaction, Newtonian interactions, friction interaction, plastic interaction…) instead of featuring only linear spring-dampers. In the models, the design of interaction is prominent.
- It promotes a constructivist, network-like, mesh-free, modelling process, rather than a mesh-discretization methodology. The physical modelling process starts from scratch. The designer assembles the basic modules as a network, by handling directly the mass-interaction formalism. No geometrical mesh of a volume or a surface needs to be a priori considered.

The mass-interaction technique is sometimes said to be quite expansive in term of processing cost, and not to be very precise – we know, for example, that simulating wave propagation by using masses and interactions introduces some numerical bias as compared to the wave equation model. It is also considered as being unstable, in the sense that a given model may diverge in certain configurations.

On the contrary, the technique is amongst the most modular. The basic masses and interactions are very elementary models of a piece of matter, that remain pertinent for the human senses (they all can be, for example, perceived through a haptic gesture device, or visually represented) and can be easily internalized by any user as representations of very basic objects. The technique is also robust since a stable network of masses and interactions behaves plausibly no matter how it was constructed. It thus enables a relevant mental model. The designer of the model is not required to refer to any continuous model of traditional physics, nor to consider the mass and spring network as a numerical analysis method. He often base his construction work on some intuition, trying to imitate or metaphorize the object he wants to model. Consequently, various modellers usable by the end-user have been introduced [Castagne & Cadoz, 02] [Evrard et al., 06] [Sod], etc.

Finally, the mass-interaction technique can be viewed as particularly generic. It has been successfully used in a large variety of applications in computer music, animation and virtual realities: sound resonator, wind and string instruments, bowed or plucked interaction, musical gesture generation, fluids, pastes, gels, sands, deformable objects, vehicles, dancing, etc.

Indeed, mass-interaction modelling applies to the modelling of any moving physical objects, particularly those in which the dynamics of the behaviour is prominent. So doing, it qualifies, as a unique feature, for the modelling of multisensory object and the building of enactive interfaces: a single model built within the mass-interaction framework, eventually multidimensional and multifrequency, may allow the synthesis at the same time of sounds, visual movements, and force-feedback data to be sensed through an haptic device, each of the phenomena being tightly correlated with each others.

References

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[Sod] Sodaplay java applet - http://www.sodaplay.com

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